

Fluorine and its significance in stomatology

(Fluor i jego znaczenie w stomatologii)

M Wróblewska^{1, A,D,E,F}, B Błaszczak^{2,B}, U Paśnik^{2,C}

Abstract – This paper discusses the main physicochemical properties of fluorine, the ways it can be absorbed into organism, its ways of accumulation and distribution within human organism and its physiological significance.

Key words – fluorine, physiological significance.

Streszczenie – W pracy przedstawiono główne cechy fizykochemiczne fluoru, drogi jego pobierania przez organizm, sposoby akumulacji i dystrybucji w organizmie człowieka oraz jego znaczenie fizjologiczne.

Słowa kluczowe – fluor, znaczenie fizjologiczne.

Author Affiliations:

1. Department and Clinic of Conservative Dentistry with Endodontics, Jagiellonian University Medical College
2. Collegium Masoviense - College of Health Sciences

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- A. The idea and the planning of the study
- B. Gathering and listing data
- C. The data analysis and interpretation
- D. Writing the article
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- F. Final approval of the article

Correspondence to:

Dr Małgorzata Wróblewska, Zakład i Poradnia Stomatologii Zachowawczej z Endodonta Collegium Medicum Uniwersytet Jagielloński, 4 Montelupich Str., PL-31-155 Kraków, e-mail: m.wroblewska@wp.pl

I. SELECTED PHYSICOCHEMICAL PROPERTIES

Fluorine (discovered in 1883 by a French Nobel Prize winner, Henri Moissan) is a gaseous element that belongs to group 7 of the periodic table. It liquefies at -118°C . Its high values of electron affinity (322 kJ/mole) and ionisation potential (1681 kJ/mole) make fluoride the least electronegative of all the elements. In room temperature, it reacts violently with numerous non-metals and metals. Fluorine is the most active non-metal; it combines even with inert gases. Fluorine is the strongest oxidiser of all the elements. It forces oxygen out of water, forming hydrogen fluoride. As one of few acids, hydrofluoric acid can etch glass.

As fluorine is highly reactive, in nature it can be encountered only in compounds. In the air gaseous fluorine combines with steam and appears as hydrofluoric acid (HF). Fluorides come back from the atmosphere along with dust, snow, rain or fog, penetrating ground and surface water. It has been observed that the intensity of fluoride absorption into plants is directly proportional to fluoride concentration in the air and the time of exposure. Low concentrations of fluorine stimulate the breathing of plants, while higher ones may limit enzymatic processes of plants.

II. ACCUMULATION AND DISTRIBUTION IN HUMAN ORGANISM

Fluorine is absorbed to human organism either in food (approximately 2/3) or in the inhaled air. In extraordinary circumstances it can penetrate skin as well. It is generally believed that around 75-90% of fluorides in human organism is food-borne, as fluorine and its compounds can be easily absorbed from liquid [1]. Several minutes after the intake, the fluoride level in blood plasma starts to increase. The fluorides in blood are absorbed predominantly by hard tissues of teeth and bones (99% of the fluoride consumed), but also by soft tissues [1].

III. PHYSIOLOGICAL SIGNIFICANCE

Fluorine is one of the micro-components related to the structure of the supporting tissue of the hard tissues found in teeth, skin or hairs. Fluorine absorbed by bone tissue can also be released from it, thanks to which isoionic and heteroionic exchanges can take place in human organism. After 24 hours after consumption, around 50% of fluoride compounds is excreted predominantly with the urine, but also with faeces, saliva, sweat and milk. Fluorides are a natural component of saliva – it contains around 2/3 of the concentration present in the plasma [1].

The fluoride concentration in saliva from the main salivary glands depends on the concentration in plasma; the former is slightly lower than the latter, amounting to around 0,4-2,6 $\mu\text{moles/L}$ [1].

It is believed that fluorides absorbed in the gastrointestinal tract subsequently return through salivary glands to saliva in an insignificant amount of below 0,2%. They can also be delivered to saliva along with chemicals containing fluorides, penetrate dental plaque, bond to oral mucosa and then undergo redistribution, heading to saliva again.

During the local application of fluorides, soft tissues can also absorb them but that is dependent on the pH. After the absorption, fluorides are dissociated; a part of them, however, bonds to calcium and is partially retained in tissues. It is probably caused by the presence of acid groups on the tissue surface and the retention of fluorides caused by the reaction with calcium. Fluorides retained in soft tissues can enrich saliva after the oral cavity is rinsed. Fluorine is released to saliva also from dental plaque and the enamel surface, where it can appear as calcium fluoride (CaF_2). The sources of the fluorides present in dental plaque are: the food consumed, oral hygiene agents, saliva, gingival crevicular fluid and enamel demineralisation processes [1].

It is generally acknowledged that fluorides are accumulated mainly in bones and teeth, i.e. hard tissues of the organism. Yet, if there is no exposure to compounds containing fluorine, the desorption process may occur. It has to be added that living organisms have a fixed balance between absorption and desorption processes [1].

Fluorides supplied to the organism have beneficial biological effects as long as they are not oversupplied; in those cases they can be carcinogenic, immunotoxic, neurotoxic or allergenic. Presently it is difficult to determine what dose of fluorine is still tolerated by living organisms and what dose is toxic. Of all trace elements essential to humans, fluorine has the lowest safety margin between the dose required by the system and the dose above which the harmful symptoms appear. The maxi-

mum acceptable daily dose is 0,25 to 1 mg. The likely toxic dose is 5 mgF per kilo of body mass; yet, even 1 mgF per kilo can have toxic effects on children. The lethal dose is 15 mgF/kg of body mass.

The toxic influence of fluorine on living organisms predominantly consists in the formation of permanent, biologically inactive complexes containing metal cations (mainly from dyads, i.e. Mg) as well as the formation of permanent hydrogen bonds with biologically relevant amide groups. A result of these is a disruption of a number of biological transformations. The inhibition of enzymes caused by fluoride ions may occur in the cases of metal-dependent enzymes as well as those in which a cofactor is not needed and fluorine blocks the enzyme directly. This type of inhibition is related to, among others, the activity of acetylcholinesterase. Fluorine also inhibits some enzymes of the Krebs cycle, fatty acid oxidization and glucose transformations. By means of inhibiting glycolysis, fluorine causes the glucose level in blood to rise. The bonding between fluorine and magnesium causes many enzymes to lower their activity level and inhibits the synthesis of antibodies, thereby impairing the defence reactions of the organism. By means of causing calcium and magnesium metabolism disorders, fluoride impacts the occurrence of hyperparathyroidism. The disturbances in the cellular transformation of calcium homeostasis increase the calcitonin production. The active fluorine penetration of the inside of the parenchymal organ cells (i.e. liver and kidney cells) may result in the appearance of concrements. However, in order to unambiguously confirm the impact of those compounds on carcinogenesis, reproductive functions or immunological processes, further research is required, especially as the exposure to fluorides is on the constant increase.

As a consequence of civilizational and industrial development, higher and higher concentrations of fluorine in the surface soil layer. The industrial sources of fluorides in the environment are predominantly aluminium smelters, steelworks, phosphatic fertiliser plants, glassworks, brickyards and cryolite processing plants. Also, energy production based on coal combustion contributes to the fluoride emission. In agricultural areas, fluorine is put in the soil as a component of phosphatic fertilisers and some crop protection chemicals. In the case of heavily contaminated soil, the organic material content and microorganism activity are reduced. At the same time, biological factors facilitate the emergence of easily assimilated organic fluorides of high toxicity. The research data more and more frequently indicate the increase of fluoride content in plants, fish, dairy products and processed meat. It is believed that fluorine supply doubles every 10 years on average [2]. As a result of medical activities, additional absorption of fluorides is related to the fluoride treatment of osteoporosis, certain inhalation narcosis agents and caries prophylaxis chemicals (fluoridisa-

tion of drinking water, pills with fluorine content, toothpastes, flosses, mouthwashes, fluoride varnishes, chewing gums with fluoride content and dental materials emitting fluorine) [2].

A relevant issue is the anti-bacterial activity of fluorine. In acidified conditions, fluorides diffuse into microorganisms via cell membrane as hydrofluoric acid (HF) formed by the combination of fluorine ion and H^+ ions from the acids produced. This compound dissociates in a bacterial cell, causing acidification and releasing fluoride ions which inhibit the metabolic activity of the bacteria. That occurs, among others, because of: the inhibition of enolase, phosphatases, sugar transportation to the inside of the cell, cation transportation and accumulation; the storage of glucose and its analogues and the disruption of the synthesis of intra- and extracellular bacterial polysaccharides [3,4].

By means of affecting the metabolism of bacteria, fluorides may have a stabilising impact on the composition of the dental plaque during sugar consumption. As it was confirmed that the development of cariogenic bacteria is dependent on the decrease of the pH resulting from sugar consumption as well as their own metabolism, it was proposed that it is possible to manipulate the composition of dental plaque and to prevent from the selection of cariogenic bacteria as long as the frequency and the range of the pH decrease can be reduced [1,3,6]. The pH-dependent anti-bacterial impact of fluorides makes the minimum fluoride concentration required to inhibit the multiplication of bacteria 50 times lower in the case of the pH equalling 5,0 than if the ambient pH is neutral [5,7]. Fluorides present in the plaque when it is metabolically inactive have a similar concentration to that in saliva (0,02-0,1 ppm). These concentrations cannot play a significant part in cariostatic processes [8]. It was also observed that the fluoride content in plaque is higher than in saliva, which may be caused by slower removal from plaque or absorbing them from other sources [7]. Moreover, the fluorine concentrations of 0,16 – 0,31 mole/L were found to inhibit the growth of cariogenic bacteria, while low concentrations of around 1 mmole/L can disrupt the production of acids, which inhibits the proliferation of cariogenic bacteria requiring a low ambient pH [8]. Studies proved that the F^- fluoride concentration within the range of 900 – 6 000 ppm triggers anti-bacterial activity, while the minimum concentration inhibiting the bacteria growth is as low as 0,019 ppm with the pH of 5,0 [9].

It was observed in 1930s that both the absence and the excess of fluorine in drinking water have negative effects on teeth; moreover, in the cases of optimal fluorine amounts in drinking water, therapeutic anticariogenic activity was noted. Because of the increases of the accessibility of fluoride sources and of the risk of enamel fluorosis, the World Health Organization decreased the recommended optimal fluorine concentra-

tion range in supply water to 0,5 – 1,0 mg/L [10]. People residing in the areas where drinking water is fluoridated have higher concentration of fluorides in the enamel as well as harder enamel itself. However, there might be a problem related to fluorosis caused by drinking water which contains excessive amounts of natural fluorides [10]. Positive and negative effects of fluorine are dependent on the dose, exposure time and the particular influence on different cells and tissues [1,9,11].

Presently, it is believed that the basic, recommended and safe mechanism of the fluorine preventive activity is local application [1,4,5,9].

Mature enamel has a 1% content of proteins and lipids and 12% content of water (amounting to 15% of diffusing capacity), while the rest are calcium phosphate salts in the form of apatite. The basic structural unit of enamel is a prism, which consists of millions of hydroxyapatite crystals [5]. Enamel is not a pure hydroxyapatite, though. It also has the so-called non-apatite phase (amorphous orthophosphates and calcium carbonates) and molecules or ions adsorbed on the surface of the crystals. Each of the $Ca_{10}(PO_4)_6(OH)_2$ crystals is wrapped in closely bonded molecules of water, which fills the space between crystals and forms pores that are the main route of ion diffusion to the tissue and in the tissue [12]. If the enamel is exposed to organic acids produced by microorganisms, the mineral substance is removed from the crystal surface, which in turn undergoes constriction. The intercrystalline spaces are enlarged and enamel turns porous, which facilitates the acid penetration and further demineralisation. Before there is a cavity, the carious change looks like a white spot with slightly affected, porous surface, which covers the layers with less minerals [8,13]. Nevertheless, it has been observed that an opposite reaction can be imposed by ions that could come back to the tissue structure via the water route and remineralise the enamel [12]. The fluorine absorbed from saliva or plaque in the fluid phase first gets between enamel prisms, creating a so-called water phase. Then fluorine ions react with enamel hydroxyapatites and replace the hydroxyl ions [59]. In that manner, fluorapatites emerge. They have better crystalline properties and they are less soluble in acids. It has been proved that fluorine in ionic form inhibits demineralisation and moves the balance towards the remineralisation of the initial damage to the enamel [14]. This is a positive phenomenon, as fluorides contribute to slowing down the loss of mineral components from the enamel or prevent that loss altogether, even when in low concentrations [15].

In order for this preventive activity of fluorine to be more effective, it should last long – therefore compounds that act as storage and reservoir of the element also play a significant part. [16]. Fluorine in the oral cavity is accumulated on the tooth surface, in dental plaque and soft tissues. On the tooth surface

and in the plaque it appears in the form of calcium- and fluorine-like precipitates [50,51]. The reservoir activates when the environment gets even slightly acidic. The accretions of calcium and fluorine precipitates start to dissolve before the process begins in enamel. Fluorine ions are released, thereby preventing form the demineralisation of the enamel [17,18].

It is believed that calcium fluoride, which appears predominantly in carious changes, is much more effective at inhibiting the demineralisation process than fluorapatite [1]. Spherical deposits of CaF_2 are covered with a “membrane” that is rich in proteins or orthophosphates, which is why the solubility of calcium fluoride increases along with the decrease of the pH. In turn, fluorine ions activate at a proper moment [1].

Studies also indicated that the enamel which undergoes demineralisation and subsequent remineralisation has higher fluoride concentration than normal, healthy enamel [1,5,18]. Fluorides are present in carious changes in the enamel, especially as the surface layer of it is thin. The accessibility of fluorides causes the emergence and formation of a cohesive and impenetrable layer.

IV. REFERENCES

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